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(54) Interferometric Telescope System

(57) - Interferometric telescope system, in which at least two polychromatic beams (5, 6), together coming from the same celestial object, interfere and form several Airy spots in the focal plane (4) of said system.

- According to the invention, the telescope system is characterized:

- by the fact that it contains a light disperser (at 14) that separates the light as a function of wavelength and is positioned on the trajectory of said polychromatic beams in the vicinity of said focal plane (4); and
- by the fact that said light disperser arranges, in said focal plane (4), said monochromatic Airy spots in a manner at least approximately adjacent to and in alignment in a direction parallel to that of their interference fringes.

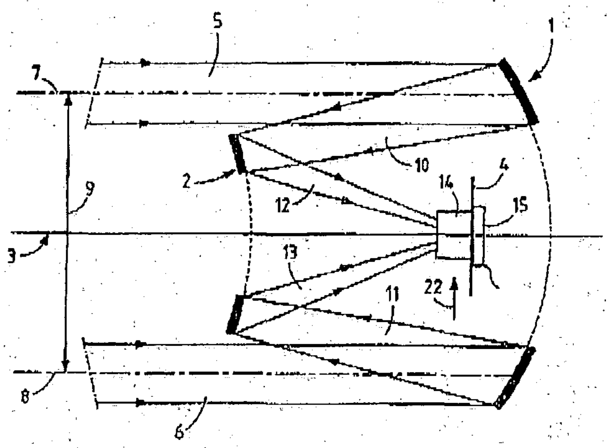

Figure 1

Description

The present invention concerns an interferometric telescope system with a two-dimensional viewing field, intended for astrometry measurements, especially global. Although not exclusively, it is particularly adapted to astrometric measurements of the GAIA program (Global Astrometric Interferometer for Astrophysics) of the European Space Agency.

It is known that an interferometric telescope system of this type causes at least two polychromatic beams, together coming from the same star, to interfere and form in its focal plane a polychromatic Airy spot enclosing interference fringes. To form said polychromatic beams, this system can contain as many telescopes as beams or a single telescope, at whose input a mask perforated with holes, whose number corresponds to that of said beams, is positioned. Moreover, in the case of a telescope of the Fizeau mask type, it is known that the interval of the interference fringes of the Airy spots is inversely proportional to the distance of the axes of said polychromatic beams to the input to said system, a distance that is generally called the "base".

In order to be able to measure and exploit, in several different spectral bands (for example, numbering six), the polychromatic Airy spot produced by such a known interferometric telescope system, an equal number of electronic matrices (for example, of the CCD type) are arranged in its focal plane, each equipped with a filter corresponding to a predefined spectral band. When the interferometric telescope system scans space, the image of a star in the focal plane (Airy spot) successively passes through different filters, which permits spectral information to be successively obtained.

Such an arrangement has serious shortcomings.

In the first place, since it consists of separating different spectral regions in the field of view of the system, it requires significant dimensions for the useful field of view and for the

focal plane of said system. For example, when six spectral bands are used, as in the GAIA program, the focal plane must contain six types of electronic matrices and therefore cannot have an area less than 40 cm × 40 cm. This arrangement therefore can only be used for complex and cumbersome interferometric telescope systems. However, even with such systems, this arrangement makes their design poorly feasible.

Moreover, in such a known interferometric telescope system, each filter-matrix pair sees, at a given instant, a different zone of space than those seen by the other pairs, since its positioning in the focal plane is different from that of the latter. The instantaneous images given by these matrices are therefore different, not only because they are associated with different colors, but because they do not precisely concern the same celestial object.

The objective of the present invention is to remedy these drawbacks and to permit implementation of a simple and less cumbersome interferometric telescope system with a relatively small field of view and focal plane, and with which the different instantaneous monochromatic images precisely correspond to the same celestial object.

For this purpose, according to the invention, the interferometric telescope system, in which at least two polychromatic beams coming together from the same celestial object interfere, is remarkable in that it contains a light disperser that separates light as a function of wavelength and is arranged on the trajectory of said polychromatic beams in the vicinity of the focal plane of said system, so that in said focal plane, several Airy spots are formed, each of which corresponds to one of the colors of said polychromatic beams, and by the fact that said light disperser, used on a two-dimensional field of view, arranges said monochromatic Airy spots in said focal plane in a manner at least approximately adjacent to and aligned in a direction parallel to that of the interference fringes of said monochromatic Airy spots.

Thus, by virtue of the present invention, it is no longer necessary to arrange, in said focal plane, as many groups of electronic matrices as there are investigated spectral bands; on the contrary, in the system of the invention, a single electronic matrix is sufficient. The field of view and focal plane of the system of the invention are therefore much smaller than those of known systems. If one compares the system of the invention with the known example of a system mentioned above, whose focal plane contains six types of matrices and an area of at least 40 cm × 40 cm, one finds that the number of matrices is divided by 6, and that it is therefore the same for the area of the focal plane, which can now be 16 cm × 16 cm.

The present invention therefore permits, on the one hand, a considerable increase in the feasibility of such an interferometric telescope system, and, on the other hand, use of a simple and less cumbersome telescope, for example, of the Cassegrain type, which has a fairly limited field of view (and therefore incompatible with a large focal plane). The possibility of using such

a telescope is all the more advantageous, since it presents little aberration and has a dioptric focal corrector that can also correct any astigmatism of said disperser.

Furthermore, it is evident that the present invention permits the taking of an instantaneous image in all spectral bands, which the prior art does not permit, as mentioned above.

Moreover, it will be noted that, by means of the present invention, the energy of a star captured by the interferometric telescope system is fully recovered by the focal plane (at almost the transmission factor of said system) without diffraction or efficiency problems, contrary to known systems.

As regards the dispersion of the monochromatic Airy spots in the focal plane, provided by the present invention, one will note:

- that its amplitude is sufficiently large to be able to separate each spectral band from the others, but sufficiently small, so that there is no possibility of confusion between the Airy spots pertaining to different stars; and
- that its direction is parallel to the interference fringes, i.e., orthogonal to the base of the system, so that the direction perpendicular to said interference fringes is not affected. This means that the interferometric dimension of interest that requires high spatial resolution and corresponds to the interval of said interference fringes is not modified by said dispersion.

This means that the interference figure concerning a star is perfectly reliable and discernible in the direction of the interfringes, while delivering the spectral information related to said star. Thus, the electronic matrix arranged in the focal plane of the system is then capable of furnishing the position, interferometric information and spectral information of each star viewed by the system.

Preferably, said light disperser is of the dioptric type. It can contain two prismatic plates attached on their oblique faces and together forming a plate with parallel places, containing a plane oblique diopter between said parallel faces.

Advantageously, said prismatic plates have equal refractive indices for a wavelength at least approximately median in the range of wavelengths corresponding to said Airy spots, and have constringences as different as possible for the extreme wavelengths of said range. For example, said prismatic plates are made, respectively, of PSK53A and FN11 glass.

In order to correct the optical aberrations of said disperser, one can associate a set of optical lenses appropriate to it. In the case where said interferometric system contains a focal correct or correct its intrinsic optical aberrations, it is advantageous that the set of said light

disperser and its set of corrective lenses are incorporated on said focal corrector, with adaptation of the latter to allow for optical interaction between said focal corrector and said disperser.

Said set of corrective lenses can include a lens with a plane face merged with the focal plane of said system.

The figures of the appended drawing will explain how the invention can be implemented better. Identical references in these figures denote similar elements.

Figure 1 schematically illustrates an interferometric telescope with two mirrors, modified according to the present invention.

Figure 2 illustrates the principle of a schematic practical example of the disperser according to the present invention.

Figure 3 shows the variations, as a function of wavelength, of refractive indices of the prismatic place forming the disperser of Figure 2.

Figure 4 illustrates a set of monochromatic Airy spots relative to the same star.

Figure 5 schematically illustrates the electronic matrix arranged in the focal plane of the interferometric telescope with three sets of Airy spots.

Figures 6 and 7 are two views of a practical variant of the disperser according to the present invention, in a direction orthogonal to the plane containing the base and optical axis of the telescope, and in a direction parallel to said base, respectively.

The interferometric telescope schematically illustrated in Figure 1, for example, of the Cassegrain type, contains in known fashion a concave mirror 1 and a convex mirror 2 facing it, centered on an axis 3 and determining a focal plane 4.

The concave mirror 1 receives from a celestial object (not shown), especially a star, two polychromatic beams 5 and 6 that are parallel, and each of which is formed of parallel rays. The respective axes 7 and 8 of said beams 5 and 6 are distant from base 9.

By reflection on concave mirror 1, said beams 5 and 6 are returned to convex mirror 2 in the form of convergent beams 10 and 11, respectively. Said convex mirror 2, in turn, reflects said convergent beams 10 and 11 in the form of other beams 12 and 13 that converge on focal plane 4, respectively.

According to the present invention, the interferometric telescope of Figure 1 contains an optical device 14 arranged on the trajectory of convergent beams 12 and 13 in the vicinity of focal plane 4 and capable of separating and dispersing the monochromatic light contained in its polychromatic light as a function of wavelength.

Moreover, the interferometric telescope contains one or more electronic matrices 15, for example, of the CCD type, capable of observing and measuring the images formed in focal plane 4.

The principal element of the device 14 is the optical disperser 16, shown in Figure 2. This disperser 16 consists of two prismatic plates 17 and 18, mounted, and even glued one against the other, by their oblique faces, forming the plane diopter 19 inclined relative to the optical axis 3 of the telescope. In addition, the other faces 20 and 21 of said plates, opposite the inclined plane diopter 18, are parallel to each other and orthogonal to said axis 3. As a result, the disperser 15 consists of a parallel plate, within which the inclined plane diopter 19 is found. It will be noted that the optical disperser 16 is seen in Figure 2 in the direction 22 parallel to base 9 (see Figure 1), whereas in Figure 1, in the case where the device 14 would be transparent, said optical disperser 16 will be seen in a direction 23 of Figure 2, orthogonal to the plane containing direction 22 and base 9 (and therefore axis 3).

The refractive indices n17 and n18 of the prismatic plates 17 and 18, respectively, are functions of the wavelength of the polychromatic light that the latter receives. Subsequently, it will be assumed, for example, that the interferometric telescope has the mission of studying six wavelength bands around wavelengths $\lambda 1$ to $\lambda 6$, respectively, originating from a celestial object.

The prismatic plates 17 and 18 are made of glass, for example, those known under the references PSK53A and FN11, which have the same refractive index n0 for a wavelength $\lambda 0$, or at least approximately median in the range of wavelengths $\lambda 1$ to $\lambda 6$ investigated by the telescope, and which, for the extreme wavelength $\lambda 1$ and $\lambda 6$ of said range, have the most different possible constringences, i.e., for which:

$$\frac{n17(\lambda o)}{n17(\lambda 1) - n17(\lambda 6)}$$

is very different from

$$\frac{n18(\lambda o)}{n18(\lambda 1) - n18(\lambda 6)}$$

In addition, the glass forming plates 17 and 18 are chosen to be prepared easily, and to be adapted to space conditions in a case where the telescope must itself be mounted onboard a satellite.

In the above example, the wavelengths $\lambda 1$, λo and $\lambda 6$ are at least approximately equal to 400 nm, 600 nm, and 800 nm, respectively.

In Figure 3, the curves 24 and 25 illustrate schematically an example of the variation of refractive indices n17 and n18 as a function of wavelength λ.

Thus (see Figure 2), when an incident polychromatic beam 26 parallel to the optical axis 3 strikes the orthogonal plane face 20 of disperser 16, it is dispersed by the oblique diopter 19 and face 21 into as many dispersed beams 27.1 ..., 27.i, ..., 27.n, as there are monochromatic colors in the incident beam. Moreover, each dispersed beam 27i, corresponding to a wavelength λi, has a fixed orientation and therefore forms on a plane orthogonal to optical axis 3, for example, focal plane 4, a spot, whose position is specific to it.

As a result, if one considers the six wavelengths λ1 to λ6 among the n that beams 5 and 6 contain, one will find the six corresponding Airy spots 31.1 to 31.6 with distinct positions of focal plane 4, with said Airy spots forming a group 30 associated with a particular celestial object (see Figure 4).

These Airy spots 31.3 to 31.6 contain an envelope 32 and interferences fringes 33 and are aligned by disperser 16 parallel to said fringes. Moreover, the dispersion obtained by disperser 16 is controlled so that said Airy spots 31.1 to 31.6 are at least approximately adjacent.

Thus, on electronic matrix 15, each celestial object a, b or c observed by the telescope of Figure 1 produces a set of Airy spots 30.a, 30.b or 30.c, on which it is possible to make the desired astrometry measurements.

In order to correct the optical aberrations of disperser 16, the optical device 14 can also contain corrective lenses 35, 36, 37, 38. If the telescope requires a focal corrector, said corrective lenses and said disperser are incorporated in the focal corrector, which is adapted as a result.

One of the corrective lenses 38 can contain a plane face 39 merged with said focal plane 4 of the system.

CLAIMS

1. Interferometric telescope system, in which at least two polychromatic beams (5, 6), together originating from the same celestial object, interfere,
characterized:

- by the fact that it contains a light disperser (16) that separates the light as a function of wavelength and is arranged on the trajectory of said polychromatic beams in the vicinity of focal plane (4) of said system, so that in said focal plane, several Airy plots (31.1 to 31.6) are formed, each of which corresponds to one of the colors of said polychromatic beams;
and

- by the fact that said light disperser (16), used on a field of view in two dimensions, arranges said monochromatic Airy spots (31.1 to 31.6) in said focal plane in a manner at least approximately adjacent to and aligned in a direction parallel to that of the interference fringes (33) of said monochromatic Airy spots.

2. System according to Claim 1,
characterized by the fact that said light disperser (16) is of the dioptric type.

3. System according to Claim 2,
characterized by the fact that said light disperser (16) contains two prismatic plates (17, 18) mounted along their oblique faces and together forming a plate with parallel faces (20, 21), containing an oblique plane diopter (19) between said faces.

4. System according to Claim 3,
characterized by the fact that said prismatic plates (17, 18) have refractive indices (n17, n18) equal for a wavelength (λo) at least approximately median in the wavelength range ($\lambda 1$ - $\lambda 6$) corresponding to said Airy spots, and have constringences as different as possible for the extreme wavelengths ($\lambda 1$, $\lambda 6$) of said range.

5. System according to one of the Claims 2 to 4,
characterized by the fact that said prismatic plates (17, 18) are made of glass PSK53A and FN11, respectively.

6. System according to one of the preceding claims,
characterized by the fact that it contains a set of optical lenses (35 to 38) associated with said light disperser (16) to correct the optical aberrations produced by said disperser (16).

7. System according to Claim 6, of a type in which a focal corrector is necessary to correct its intrinsic optical aberrations,
characterized by the fact that the set of said light disperser and its set of associated corrective lenses is incorporated in the focal corrector with adaptation of the latter to allow for optical interaction between said focal corrector and said disperser.

8. System according to one of the Claims 6 or 7,
characterized by the fact that said set of corrective lenses (35 to 38) contains a lens (38) with a plane face (39) merged with said focal plane.

9. System according to one of the Claims 1 to 8,
characterized by the fact that it is of the Cassegrain type.

INTERNATIONAL SEARCH REPORT

International Application Number

EP 98 40 0703

A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	Int. C1.B
A	US 5 108 168 A (NORBERT MASSIE A ET AL) April 28, 1992 *summary: figures I, 4-6, 8* *column 3, line 56-column 4, line 6 * —	1.9	G02B23/02 G0189/02
A	US 5 317 389 A (HOCHBERG ERIC B ET AL) May 31, 1994 *summary: figure 1* *column 2, line 34-line 49* *column 5, line 45-line 65* —	1.2	

A	US 4 215 273 A (KOCH NOMAN G ET AL) July 29, 1980 *summary: figures 1,2* *column 2, line 38-column 66* *column 5, line 9-line 24*	1.2, 6.7	
A	K. H. ELLIOT: "A novel zoom-lens spectrograph for a small Astronomical telescope" MONTHLY NOTICE OF THE ROYAL ASTRONOMICAL SOCIETY No. 281 July 1, 1996 Pages 158-162, XP002051341 *summary: figure 1* *page 1. paragraph 2* —	1.9	G02B

☐ Further documents are listed in the continuation of box C.

☐ Patent family members are listed in annex.

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Date of the actual completion of the international search July 8, 1998	Date of mailing of the international search report
Name and mailing address of the ISA THE HAGUE	Authorized officer Jakober,. F.

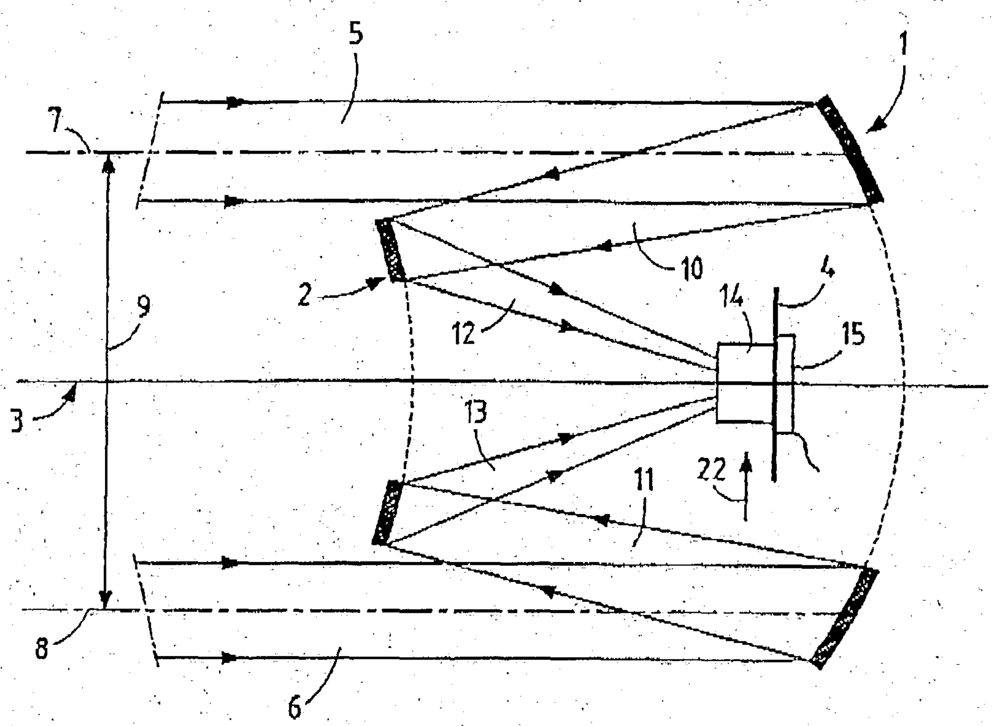

Figure 1

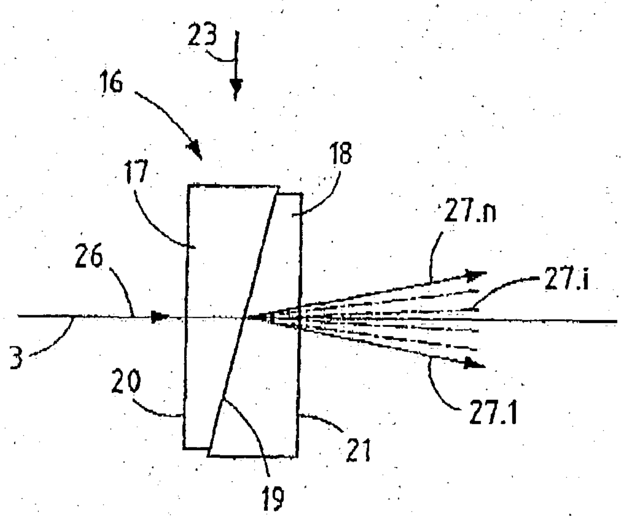

Figure 2

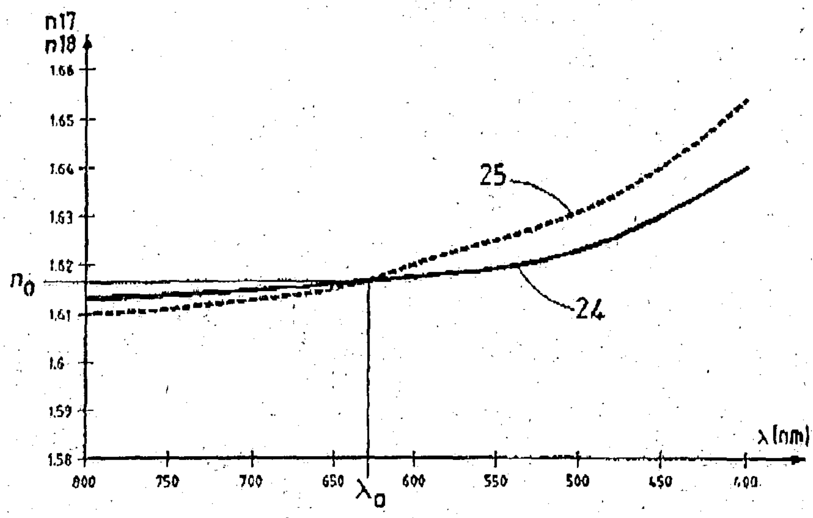

Figure 3

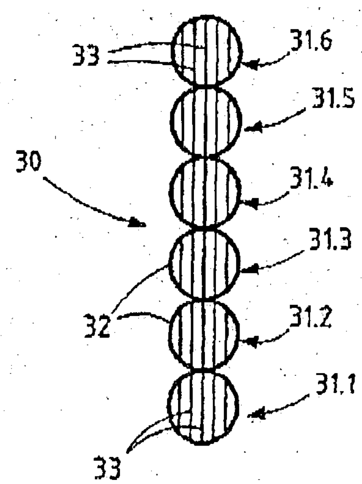

Figure 4

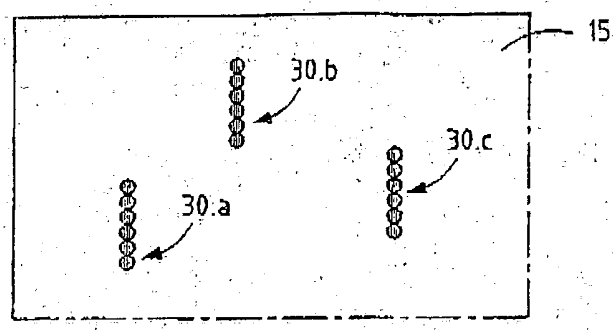

Figure 5

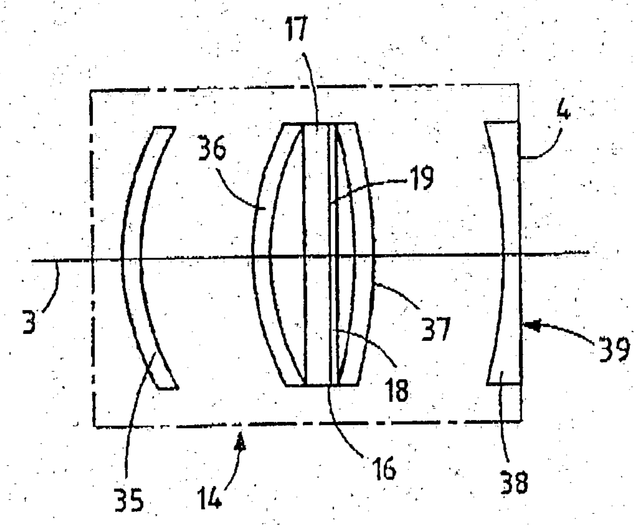

Figure 6

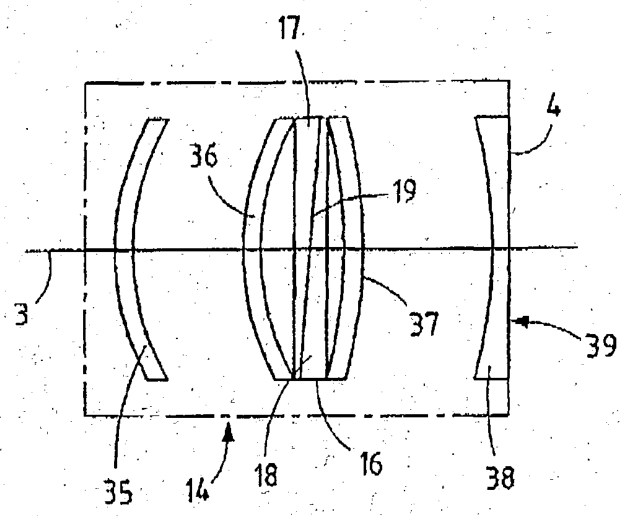

Figure 7